SURFICIAL MATERIALS AND SOILS OF PAULDING COUNTY, OHIO*

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Vast differences exist among the major dark-colored gleyed soils of the lake plain of Paulding and adjacent counties in northwestern Ohio. A complete detailed soil survey was initiated in Paulding County in August, 1952. Shortly after these operations were begun, it became apparent that not only were there major differences among these soils, but that they blended very imperceptibly from one to another. These variations accounted for highly significant differences in soil management, crop yields, and prices paid per acre for farm land. The basic reason for these differences had not been determined.

PURPOSE OF STUDY

This study was set up with three purposes in mind: 1) to determine why these soils behave so differently in their respective areas of occurrence when there is no sharp line of demarcation; 2) to determine whether these variations are due to geologic factors; and 3) if geologic phenomena are responsible for the differences in these soils, what are they and how could they be used as an aid in mapping the distribution of these various soils?

INTRODUCTION

This paper concerns primarily the Paulding Basin, which includes all land lying within the area that has as its perimeter the highest Maumee beachridge on the south from Findlay to Fort Wayne, and on the northwest from Fort Wayne

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to the vicinity of West Unity in Williams County, and the Defiance moraine on the east from the vicinity of Wauseon in Fulton County to Findlay (see fig. 1).

In a normal year a traverse from the southwestern corner to the northeastern corner of Paulding County discloses a significant gradual decrease in crop yields, much thinner average crop stands, a greater increase in occurrence of crop failures, a greater degree of damage to growing crops by heavy rainfall, a greater degree of ponding of water on the soil surface, much slower response to drainage, the need for considerable more tillage in the preparation of an adequate seedbed, and a progressively later planting season in the spring.

Failures to obtain good stands of crops immediately following seeding are common in large portions of eastern Paulding County and adjoining areas in neighboring counties. During dry periods, seeds do not sprout because the soil surface is too cloddy and becomes too dry. During excessively wet weather, the soil surface runs together, becomes puddled and dries out very slowly. These conditions are especially troublesome on the lower elevations of the Paulding Basin.

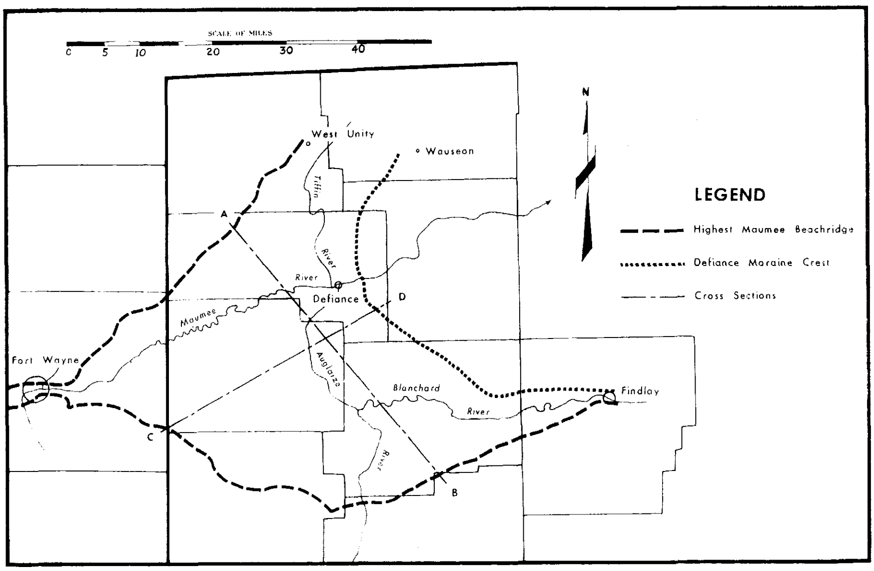

FIGURE 1. Location of elevation cross-sections AB and CD in Paulding Basin, northwestern Ohio.

In the heart of the Paulding Basin many soils respond very slowly to tile drainage. Relatively few tile drainage systems have been installed. Toward the perimeter of the basin with increasing elevation more and more tile have been used for drainage. The soils show significantly greater beneficial response to artificial drainage than those at lower elevations near the center of the basin.

Land values in 1952 for the moderately fine-textured soils in the southwestern part of the county varied from 350 to 400 dollars per acre. Toward the northeastern part of the county land values tended to decrease progressively to less than 150 dollars per acre for the very fine-textured soils.

Planting dates, barring interruption by wet weather, are about two weeks earlier in the southwestern than in the northeastern part of the county.

A traverse from any point on the Defiance moraine or the highest Maumee beachridge into the center of the Paulding Basin reveals these same problems to be just as discernible and significant.

The first soil survey of Paulding County recognized the deposition of lacustrine materials on the glacial till, but at that time it was the opinion of Lewis and Shiffler (1915, p. 14) that these lacustrine deposits were present on nearly all areas in the lake plain. The dark colored lake plain soils were all classified as Clyde clay. The Paulding soil series was distinguished from Brookston soils and established during the soil survey of Putnam County (Taylor et al., 1936). They considered these soils to have "extremely heavy and extremely impervious silty clay" subsoils underlain by "impervious heavy plastic glacial till material." Rogers and Fowler (1947) defined the Paulding series as being "developed on very heavy calcareous glacial clay till of lake plains." It was described as differing from the Brookston soils of the lake plain (now called Hoytville) "in having heavier, more impervious clay subsoils and substrata that contain little or no coarse material." These concepts were used by the Soil Conservation Service in mapping individual farms prior to 1952.

DESCRIPTION OF THE PAULDING BASIN

The topography, except in the vicinity of the beachridges, moraines, and stream channels, is very smooth and has very low gradient. Topographic maps of the U. S. Geological Survey show the gradient to vary between 4 and 7 ft/mile in the outer portion of the basin and between 1 and 3 ft/mile in the lower portion. In some areas the gradient is less than 1 ft/mile.

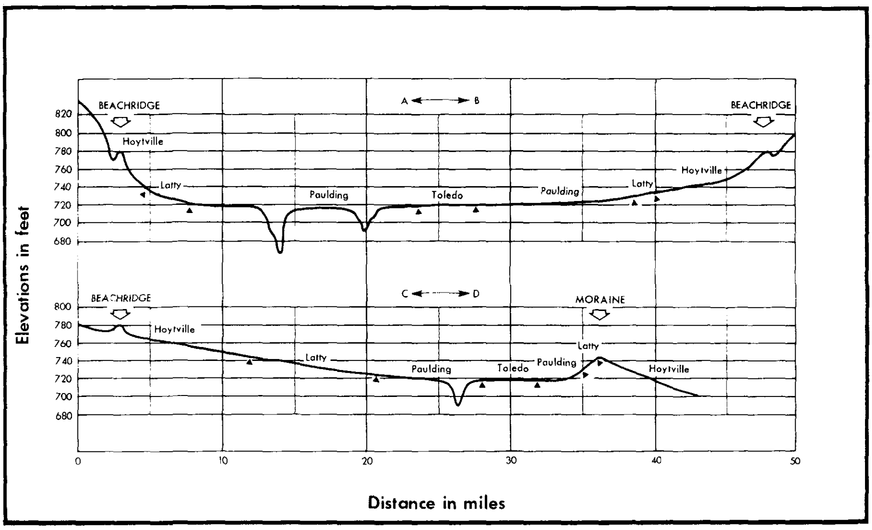

FIGURE 2. Elevations along cross-sections AB and CD, Paulding Basin, northwestern Ohio.

The Maumee River falls at the rate of 1.3 ft/mile (Krolczyk, 1954, p. 33). That portion of the Auglaize River within the lake plain has a gradient of about 1.8 ft/mile.

The location of two cross-sections of the basin are shown in figure 1. Cross-section AB begins at a point behind the highest northerly Maumee beachridge about 2 miles southwest of Williams Center in Williams County, extends in a southeasterly direction and crosses the highest southern Maumee beachridge in Allen County about 2.5 miles southwest of Columbus Grove. Cross-section CD begins behind the highest southerly Maumee beachridge at a point about 1 mile west of the Ohio-Indiana line and extends in an east-northeast direction across the Defiance moraine about 1 mile southeast of Ayersville in Defiance County.

These cross-sections (fig. 2) portray the depressional terrain that constitutes the Paulding Basin. Only the major drainage channels are shown. Most of the highest Maumee beachridge lies between elevations of 780 and 790 ft. That portion of the Defiance moraine lying adjacent to the major part of the Paulding Basin rises from the basin floor to elevations between 730 and 750 ft. The elevation of the lowest part of the basin floor, exclusive of those areas affected by erosional factors, is about 710 ft.

Several significant areas of sand, 50 to more than 200 acres in extent, occur at elevations of 710 to 725 ft in Auglaize, Brown, and Emerald Townships in Paulding County. Small widely scattered bodies of sand, 0.5 to more than 10 acres in extent, are found in many parts of the basin. These sand areas are not shown on any of the figures because of their erratic nature of occurrence.

The southern two-thirds of the basin is underlain with limestones of the Columbus and Monroe groups; the northern one-third is underlain with Ohio shale. A small area at the northern edge of the Paulding basin is underlain with basal shales of the Mississippian formation. (Stout et al., 1944).

The area has been covered by several distinct stages of glaciation, the last one being the Wisconsin. There is abundant evidence that the lake basin existed during at least one of the earlier stages of glaciation (Leverett and Taylor, 1915, p. 318). Just prior to the formation of any known glacial lakes the ice was "in a waning stage of the Fort Wayne phase of the Cary glacial substage in the Erie Basin" (Hough, 1958, p. 139). Hough (1958, p. 140) also pointed out that the "first major lake stage in the Erie basin was formed by recession of the margin of the glacial ice eastward from the southwestern end of the basin, leaving a low area between the ice and the Fort Wayne moraine." This lake had an elevation of 800 ft and discharged to the Wabash River at Fort Wayne (Hough, 1958, p. 140). Leverett and Taylor (1915, p. 322) suggested that the ice retreated as much as 25 to 30 miles behind the position of the Defiance moraine before readvancing to that position. Hough (1958, p. 144) believes that the ice may have retreated much farther than this point before its readvance. The Defiance moraine marks the position of the ice border during a considerable part of the life of the First Lake Maumee (Leverett and Taylor, 1915, p. 279).

Vegetation

In the early days the Black Swamp of which the Paulding Basin is a part was described as a "morass that varied seasonally as well as annually with changes in precipitation" (Kaatz, 1955, p. 2). Kaatz (1955, p. 7) referred to it as a "thick and almost tractless forest." The poorly drained soils of the Paulding Basin were covered with a dense growth of black and white ash, American elm, shagbark and big shell bark hickory, basswood, swamp white oak, pin oak, burr oak, sycamore, silver maple, and cottonwood; some of the boggy areas were covered with wet land grasses and sedges; the better drained areas supported a dense growth of beech, basswood, white oak, red oak, and sugar maple (Baker et al., in press).

Nearly all of the original dense stand of timber has been cleared. To some extent the few remaining areas of timber have changed in character. This condition is especially true in areas of the Paulding soil series where pin oak and swamp white oak have become major species.

PROCEDURE AND OBSERVATIONS

The Humic-Gley soils were selected for this study because they represent nearly 75 percent of the total soil area on the lake plain in the Paulding Basin. After some initial study it was apparent that the Humic-Gley soils above an elevation of about 735 ft had developed from calcareous glacial clay till. The till displays evidence of having been reworked and the surface smoothed to some degree by wave action in glacial Lake Maumee. However, there is little evidence of any significant amount of deposition of lacustrine materials on the surface of the till plain in these areas. The Hoytville series was split from the old Brookston series to cover these Humic-Gley soils. As work progressed it became apparent that the Paulding soils were developed from very fine-textured lacustrine materials, not very fine-textured till. The absence of any coarse fraction, the presence of laminations or varves in the lacustrine materials, and the presence of glacial clay till beneath the lacustrine materials supported this view.

A series of complete soil profiles were sampled along several transects to determine the soil characteristics (fig. 3). These transects were set up in such a manner that they crossed from the area of soils developed from clay till to the area of soils thought to be developed from lacustrine materials.

Transect A began in section 20 of Benton Township and ended in section 33 of Auglaize Township in Paulding County. Transect B began in section 19 of Hoaglin Township, Van Wert County, and extended to the extreme northwest corner of Putnam County. Transect C was originated in section 20 of Harrison Township and ended in section 24 of Emerald Township in Paulding County. A total of 25 complete soil profiles were taken along these three transects.

The results of the analyses of these samples together with additional information gathered in the field in Paulding and adjoining counties were used to develop and substantiate the soil-parent material relationships, to assist in the explanation of the variations in response to management and behavior of these soils, and to serve as an aid for separating the various soils in the field. The clay content of the subsoil along these transects ranged from 45 percent in those soils developed entirely from glacial clay till to more than 75 percent in those soils developed entirely from very fine-textured lacustrine materials. There are also major differences in structure and consistence in these various soil areas.

Hoytville Soils

Typical profiles of Hoytville soils in the Paulding Basin have a range in clay content of 45 to about 50 percent in the subsoil. Sand content varies from 12 to about 18 percent in both the subsoil and underlying till. The content of clay in the till varies from 40 to slightly less than 50 percent; the till contains a small but significant quantity of coarse skeleton consisting of Ohio shale, limestone, and igneous materials. The carbonate content ranges from 15 to 25 percent. The B horizons in these Hoytville profiles have weak textural development in terms of clay accumulation, whereas the angular blocky structure is strongly developed (Baker et al., in press).

Hoytville profile, VW-1, located 4 miles north of Van Wert in Hoaglin Township, Van Wert County, or in SW¼ SW¼ Section 19, T.3E., R.1S., on a slope of less than 1 percent was selected as being typical of the Hoytville series. Laboratory data are given in table 1. The description of this profile is as follows: (all Munsell color readings are for moist soil)

A_p	0– 8 in.	Very dark grayish brown (10YR 3/2) silty clay; weak fine angular blocky structure; firm when moist, very hard when dry; high organic matter content; lower boundary is abrupt.
B_{21g}	8–17 in.	Dark gray (10YR 4/1) clay with many, medium, distinct dark reddish brown (5YR 3/4) mottles; weak coarse prismatic structure which breaks into moderate fine angular blocky structure; firm when moist, very hard when dry; lower boundary is gradual.
B_{22g}	17–45 in.	Gray (10YR 5/1) clay with many, medium, distinct yellowish brown (10YR 5/6) and brown (7.5YR 4/4) mottles; strong medium angular blocky structure; firm when moist.
C_1	45–48 in.	Calcareous gray (10YR 5/1) and yellowish brown (10YR 5/6) clay till; massive; very firm when moist.
C_2	82–86 in.	Calcareous clay till similar to the above horizon.

Paulding Soils

Typical samples of Paulding soils have a range in clay content in the subsoil of 65 to more than 75 percent. Paulding soils have accumulated very little, if any, clay in their B horizons. The substratum beneath the solum contains as much or more clay than the subsoil. The amount of sand in the subsoil and substratum is usually less than 7 percent and is commonly less than 3 percent. There is no coarse skeleton present in the lacustrine material above the underlying clay till. The carbonate content varies from 15 to 25 percent.

These soils have moderate to well developed structure to depths of about 24 in. Below this point the soil structure is very poorly developed, if any has developed at all.

Paulding profile, PD–S8, located about three-quarters of a mile northwest of Junction in Emerald Township, Paulding County, or in SW¼ NW¼ Sec. 24, T.3N., R.3E., on a slope of less than 1 percent was selected as being typical of the Paulding series. Laboratory data are given in table 1. The description of this profile is as follows: (all Munsell color readings are for moist soil)

A_p	0– 6 in.	Dark gray (2.5Y 4/1) clay; massive to weak coarse granular structure; becomes more massive in lower 4 in.; firm when moist, extremely hard when dry, sticky and moderately plastic when wet; lower boundary is clear.
B_{1g}	6– 9 in.	Gray (N 5/0) fine clay with many, fine, distinct yellowish brown (10YR 5/8 to 6/8) mottles; massive to very weak fine angular blocky structure; very firm when moist, plastic and sticky when wet, extremely hard when dry; lower boundary is gradual.
B_{21g}	9–22 in.	Gray (N 5/0 to 4/0) fine clay with common, coarse, distinct yellowish brown (10YR 5/8) mottles; strong medium angular blocky structure; very firm when moist, sticky and plastic when wet, extremely hard when dry; lower boundary is gradual. (Sampled at 9–16 and 16–22 in.)
B_{22g}	22–30 in.	Gray (N 5/0) fine clay with many, fine, distinct yellowish brown (10YR 5/6) mottles; massive to weak angular blocky structure; very firm when moist, sticky and plastic when wet, extremely hard when dry; lower boundary is diffuse.
B_{3g}	30–48 in.	Gray (5Y 5/1 to 6/1) fine clay with many, fine, distinct yellowish brown (10YR 5/6) mottles; massive; very firm when moist, plastic and moderately sticky when wet; no roots evident; lower boundary is clear and wavy. (Sampled at 30–39 and 39–48 in.)
C_1	48–63 in.	Dark yellowish brown (10YR 4/4) calcareous fine clay with common, coarse, distinct gray (5Y 5/1) mottles and with coarse (one inch) light gray splotches of calcareous material; massive; very firm when moist.
C_2	63–80 in.	Yellowish brown (10YR 5/6) calcareous fine clay distinctly mottled with gray (N 5/0) on vertical faces and along laminae surfaces; weakly laminated, firm when moist.
C_2	80–90 in.	Olive brown (2.5Y 4/4) calcareous laminated fine clay mottled with gray (N 5/0) coatings on vertical faces and horizontally along laminae surfaces.
C_2	90–98 in.	Dark yellowish brown (10YR 4/3) calcareous laminated fine clay faintly mottled with gray (N 5/0) along laminae surfaces.

Latty Soils

An extensive belt, from 1 to 5 miles wide, occurs between the areas of typical Hoytville and typical Paulding soils in which the thickness of the lacustrine materials is rather thin—commonly less than 42 in. The soils in this area have some of the characteristics of both Hoytville and Paulding soils. During average to dry weather they respond similarly to Hoytville soils; during wetter than average weather they have many of the characteristics of Paulding soils, but to a lesser degree. The Latty series was introduced during the survey of Paulding County for soils of this belt.

In this area the clay content of the subsoil ranges from 50 to about 60 percent, and that of the substratum varies from 40 to slightly above 50 percent. In some areas there is a sharp line of contact between the lacustrine materials and the underlying clay till. In other areas no contact line is evident because the two materials have been blended into a heterogenous mixture. The sand content in the subsoil varies from 8 to about 15 percent. The substratum contains 15 to 25 percent of carbonates. These soils have stronger development of structure in the lower part of the solum than Paulding soils but not quite as strong as that of Hoytville soils.

Latty profile, number 10, located 2 miles south of Paulding in Jackson Township, Paulding County or in SW¼ SW¼ Sec. 19, T.2N., R.3E., on a slope of less than 1 percent, was selected as being typical of the Latty series. Laboratory data are given in table 1. The description of this profile is as follows: (The Munsell color readings are for moist soil)

A_p 0– 7 in. Very dark gray (10YR 4/1) clay; massive to weak medium granular structure; very firm when moist, hard when dry; lower boundary is abrupt.

B_{21g} 7–18 in. Gray (2.5Y 6/1) clay with many, medium to coarse, prominent yellowish brown (10YR 5/6) mottles; moderate medium angular blocky structure; very firm when moist, sticky and plastic when wet; lower boundary is diffuse.

B_{22g} 18–32 in. Grayish brown (2.5Y 5/2) clay with many, medium to coarse, distinct yellowish brown (10YR 5/6) mottles; weakly developed prismatic structure that breaks into moderate coarse angular blocky structure; very firm when moist, plastic and sticky when wet; lower boundary is clear and wavy.

B_{23g} 32–40 in. Light olive gray (5Y 6/2) clay with common, medium, distinct yellowish brown (10YR 5/4) mottles; moderate medium and coarse angular blocky structure; very firm when moist, plastic and sticky when wet; lower boundary is clear.

C_1 40–48 in. Mottled yellowish brown to dark yellowish brown (10YR 5/6 to 4/4) gray to light gray (5Y 5/1 to 6/1) and white (2.5Y 8/2) calcareous clay; white material is $CaCO_3$ and occurs in patches in the mass; occasional small patches of very dark grayish brown (10YR 3/2) material; massive; very firm when moist; plastic when wet.

D 48–60 in. Gray to light gray (N 6/0) calcareous clay till mottled with dark yellowish brown (10YR 4/4) yellowish brown (10YR 5/6) and dark brown (10YR 4/2), gray makes up about 40 percent of the total mass; massive; very firm when moist, plastic when wet.

Toledo Soils

A more recent accumulation of lacustrine materials was deposited at some subsequent time over the lacustrine materials from which Paulding soils developed. The Toledo soils, developed from these younger materials, encompass an extensive area in eastern Paulding, the northwestern part of Putnam, and the southern part of Defiance Counties. They blend gradually into the Paulding soils surrounding them.

The Toledo soils have higher silt and lower clay content than the Paulding soils. They also have thicker surface soils, stronger development of structure in the lower subsoil and respond more readily to tile drainage and other management practices. In some areas they are slightly stratified with thin lenses of fine sand.

The subsoil and upper substratum contains slightly less than 40 to about 55 percent of clay. Three Toledo profiles which were sampled to depths sufficient to reach nonconforming underlying materials indicate that the entire area is underlain with Paulding-like materials that contain 65 to more than 75 percent of clay at depths of 5 to 8 ft. These profiles reveal a rather sharp line of contact between these materials. Sand content of the Toledo soil material is usually less than 6 percent. The parent material contains 15 to 25 percent of carbonate. These soils have well developed structure throughout the solum.

Toledo profile, PD–2, located 3.5 miles northeast of Oakwood in Brown Township, Paulding County, or in NW¼ NE¼ Sec. 13, T.2N., R.4E., on a slope of less than 1 percent was selected as being typical of the Toledo series. Laboratory data are given in table 1. The description of this profile is as follows: (The Munsell color readings are for moist soil)

A_{11}	0– 3 in.	Very dark gray (10YR 3/1) silty clay loam; moderate fine and medium subangular blocky structure; moderately firm when moist; very hard when dry.
A_{12}	3– 6 in.	Very dark gray (10YR 3/1) silty clay with few, fine, faint olive (5Y 5/3) mottles; strong medium subangular blocky structure; moderately firm when moist, very hard when dry; lower boundary is clear.
B_{21g}	6–10 in.	Dark gray to gray (5Y 4/1 to 5/1) silty clay with common, fine, faint yellowish brown (10YR 5/4) mottles; strong fine angular blocky structure; firm when moist; moderately plastic and slightly sticky when wet; lower boundary is gradual.
B_{22g}	10–28 in.	Gray (N 5/0) silty clay with many, medium, prominent yellowish brown and brownish yellow (10YR 5/4 to 6/8) mottles; very strong, medium and coarse, angular blocky structure; very firm when moist, moderately plastic and slightly sticky when wet; lower boundary is gradual.
B_{23g}	28–36 in.	Gray (5Y 6/1) silty clay with common, coarse, prominent yellowish brown (10YR 5/6) mottles; moderate medium prismatic structure which breaks into strong coarse angular blocky structure; very firm when moist, slightly plastic and slightly sticky when wet; lower boundary is gradual.
B_{24g}	36–54 in.	Mottled gray (5Y 6/1) and yellowish brown (10YR 5/6) silty clay; weak medium angular blocky structure; firm when moist, slightly plastic when wet; lower boundary is clear and wavy.
C_1	54–57 in.	Gray and yellowish brown calcareous silty clay of lacustrine origin; material is weakly laminated; firm when moist.
C_2	82–86 in.	Gray and yellowish brown calcareous silty clay of lacustrine origin, finer textured than that above.

Other Observations

A number of observations in the field add additional support to the theory of very fine lacustrine deposits over clay till. One of the most striking of these observations was made on the high banks of the Little Auglaize River in Section 28 in Brown Township, Paulding County. At this point the river has scoured a sheer bank of about 25 ft in height into the upland soil materials. The very fine textured lacustrine deposits over the clay till are about 10 ft thick. They display well defined varves in the lower part of the materials. The contact between the very fine textured lacustrine materials and the clay till is very clear and sharp.

Within the area of lacustrine deposits are scattered knolls or ridges of till that project through the surface of the lacustrine mantle. These areas are easily recognized by the differences in the soils developed on them and the presence of pebbles common to the till. The soils are comparable to those developed from glacial till in the major part of the till plain, but they differ considerably from those soils developed from very fine-textured lacustrine materials in the immediate vicinity of the till island.

TABLE 1

Particle size distribution, pH, organic matter content and $CaCO_3$ equivalent of Paulding, Latty, Hoytville and Toledo soils

Horizon	Depth in in.	pH	Organic matter	$CaCO_3$ equiv-alent	Total sands 2–.05mm %	Silt .05–.002mm %	Clay <.002mm %	Texture class
Hoytville clay, VW-1								
A_p	0–8	6.5	5.5		15.3	40.5	44.2	silty clay
B_{21g}	8–17	6.5			15.9	37.4	46.7	clay
B_{22g}	17–45	7.2			13.9	36.0	50.1	clay
C_1	45–48	7.4			14.6	36.8	48.6	clay
C_2	82–86	8.0			21.0	38.1	40.9	clay
Paudling clay, PD-S8								
A_p	0–6	6.7	5.5		4.5	31.4	64.1	clay
B_{1g}	6–9	6.4	3.7		3.0	27.8	69.2	clay
B_{21g}	9–16	6.5			2.6	25.5	71.9	clay
B_{21g}	16–22	6.6			4.0	25.0	71.0	clay
B_{22g}	22–30	6.9			3.2	23.2	73.6	clay
B_{3g}	30–39	7.2			2.9	23.7	73.4	clay
B_{3g}	39–48	7.5		1.2	2.2	22.5	75.3	clay
C_1	48–63	8.1		18.9	3.7	30.7	65.6	clay
C_2	63–80	8.1		17.5	0.6	19.7	79.7	clay
C_2	80–90	7.9		18.2	0.4	18.4	81.2	clay
C_2	90–98	8.0		19.9	0.4	18.6	81.0	clay
Latty clay, PD-10								
A_p	0–7	6.6	5.2		12.7	38.6	48.7	clay
B_{21g}	7–18	7.1	1.9		10.9	31.3	57.8	clay
B_{22g}	18–32	7.4			10.8	30.4	58.8	clay
B_{23g}	32–40	7.6		2.1	11.2	28.0	60.8	clay
C_1	40–48	7.6		12.0	17.8	37.8	44.6	clay
D	48–60	7.7		22.0	16.4	43.8	39.8	silty clay loam
Toledo silty clay, PD-2								
A_{11}	0–3	6.7	9.9		3.0	59.3	37.7	silty clay loam
A_{12}	3–6	7.1	7.0		2.8	55.7	41.5	silty clay
B_{21g}	6–10	7.2	4.1		3.0	52.2	44.8	silty clay
B_{22g}	10–28	7.1	2.6		3.3	46.4	50.3	silty clay
B_{23g}	28–36	7.2			3.6	46.1	50.3	silty clay
B_{24g}	36–54	7.3			4.2	47.0	48.8	silty clay
C_1	54–57	7.7		5.4	5.5	51.5	43.0	silty clay
D	82–86	7.5		15.9	1.4	41.4	57.2	silty clay

The thickness of the very fine-textured lacustrine materials in the Paulding Basin varies from zero to more than 14 ft. Survey work revealed a significant difference in thickness of deposition from one point to another, but it is estimated that most of that portion lying below an elevation of 725 ft has more than 4 ft of lacustrine deposits. One boring in Section 2, Washington Township, Paulding County, disclosed a depth of more than 14 ft to clay till. Many of the deeper examinations displayed the presence of varves or laminae in the lower part of the very fine textured lacustrine deposits.

The detailed soil survey of Paulding County and reconnaissance survey of adjoining areas reveal that there is a significant relationship of these lacustrine materials to general relief (fig. 2). The vast majority of Paulding soils lie below an elevation of 730 ft. Several small areas are found up to an elevation of 735 ft. The major portion of the Latty soils is present between elevations of 725 and 740 ft. Locally they have been mapped several feet above or below these elevations. The Hoytville soils rarely occur below an elevation of 735 ft in this basin. The Toledo soils are found in a broad uniform flat that lies at an elevation of 710 to slightly above 720 ft.

DISCUSSION

The relationship of the soils to the elevations at which they occur, the variations in thickness of the very fine-textured lacustrine materials, and the differences in the characteristics among the several soil series are significant. From the evidence presented it must be concluded that the center of this basin has accumulated a mantle of very fine-textured materials of lacustrine origin; that this mantle is quite variable in thickness; that this mantle, as evidenced by the Paulding and Toledo soils, has been deposited at two different times although these periods may not have been far apart; and that the soils derived from the thick lacustrine deposits (Paulding soils) vary somewhat from those developed from thin deposits over clay till (Latty soils). These three soils vary from the Hoytville soils developed from clay till. Figure 3 shows the relationship of the areas of occurrence of these soils.

The Hoytville and Toledo soils have A horizons that are 6 to 9 in. thick while those of Paulding soils usually vary between 4 and 6 in. in thickness. The thickness of the A horizon of Latty soils is intermediate between that of Hoytville and Paulding soils, usually 6 or 7 in.

Hoytville and Toledo soils on the average have darker colored A horizons than either Paulding or Latty soils. When they are moist, these soils usually have a very dark gray color (10YR 3/1) as determined by the Munsell color chart, but in some areas the color of Hoytville is very dark grayish brown (10YR 3/2). The color of the A horizon of Paulding and Latty soils is usually dark gray (10YR 4/1); in some areas it is slightly darker.

Hoytville and Toledo soils have strongly developed structure throughout their sola except for local areas where the structure is only moderately developed in the lower part of the B horizon. Paulding soils have moderately to strongly developed structure only to an average depth of 24 in. Below this depth the structure is very weakly developed or massive in the lower part of the solum. In the lower part of the B horizon of Latty soils the structure is more strongly developed than that of Paulding soils, but not as well developed as that of Hoytville soils.

The consistence of the B horizons of Hoytville and Toledo soils is firm or very firm when moist and slightly sticky and plastic when wet. The B horizons of Paulding and Latty soils are more firm when moist and more sticky when wet than those of Hoytville and Toledo soils. On drying the surface soils of Paulding and Latty become extremely hard; thus, they work up very cloddy. Hoytville and Toledo soils become hard on drying, but to a much lesser degree.

The soils derived from thin deposits of fine-textured lacustrine clay material have significant characteristics and behavior as compared with those developed entirely from clay till. The thicker deposits of very fine-textured lacustrine clays

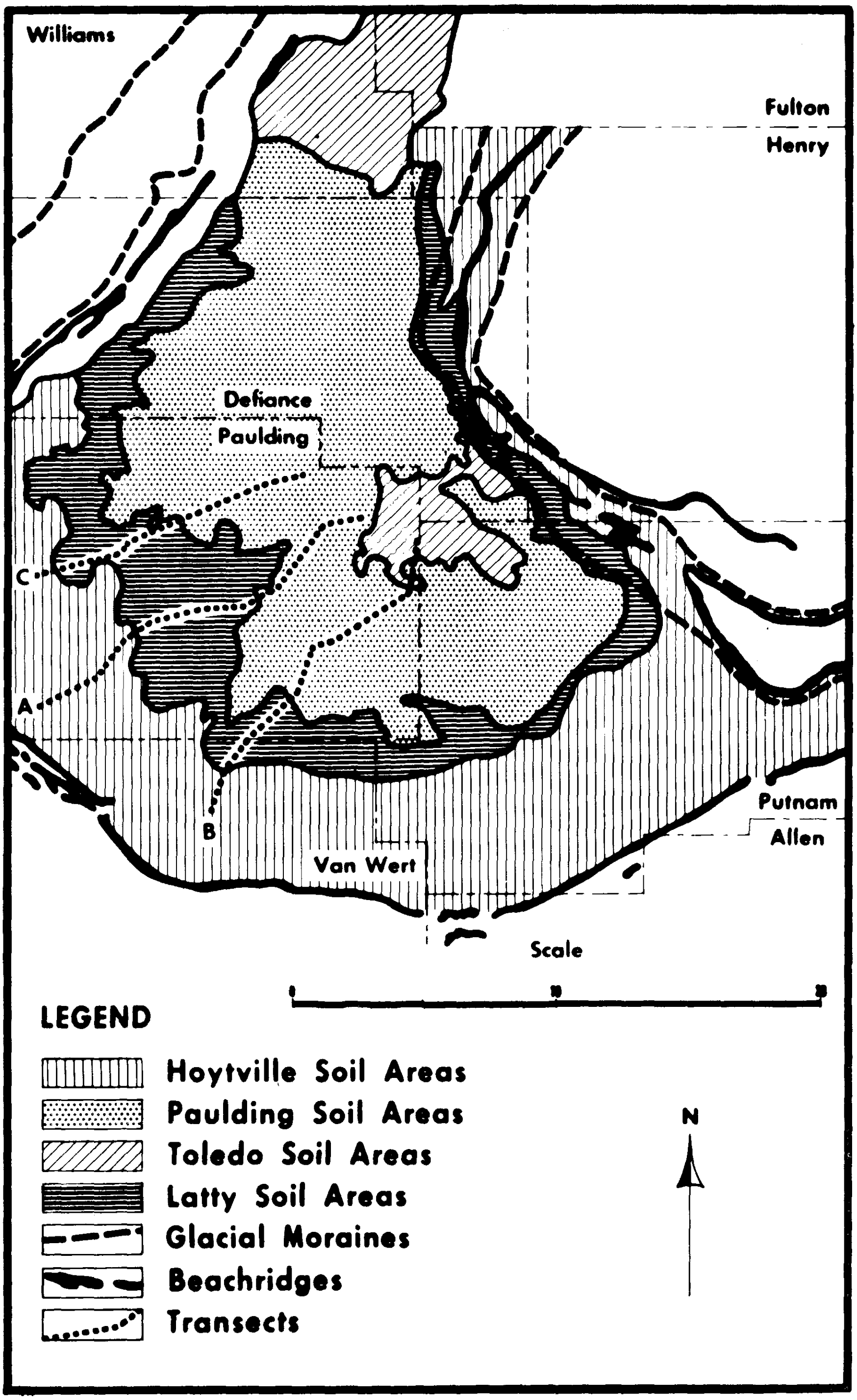

FIGURE 3. Distribution of Paulding, Latty, Hoytville, and Toledo soils, Paulding Basin, northwestern Ohio.

become highly significant in relation to soil characteristics when the lacustrine materials exceed a thickness of 42 to 48 in. and the clay content exceeds 60 to 65 percent. On the other hand the Toledo soils, developed entirely from fine-textured lacustrine materials, have many characteristics similar to those of Hoytville soils and are their equal in response to management. These soil characteristics are related to the higher silt and lower clay content than in the Paulding soils, better development of structure in the lower part of the solum, and the thicker, darker-colored surface horizons.

Both the Hoytville and Toledo soils respond readily to tile drainage and have very high productive capacity. Good seedbeds may be prepared on these soils; they produce very good stands of crops and high yields under average management.

The Paulding soils respond very slowly to tile drainage, and crops are drowned out frequently. They often have poor crop stands, even frequent complete crop failures. Because these soils work up very cloddy, seedbeds favorable to high germination and the establishment of good crop stands are very difficult to prepare. When Paulding soils become completely saturated and puddled following seeding, young plants either drown or cannot emerge because of severe crusting of the soil surface.

The Latty soils respond more like the Hoytville soils during favorable weather, but assume to a lesser degree many of the characteristics of Paulding soils during wet weather. They do not drain as readily as Hoytville soils, are somewhat more difficult to prepare into adequate seedbeds, and generally produce somewhat lower yields and have more crop failures than Hoytville soils.

THEORIES

Several theories have been developed concerning the nature of the till plain and the environment of deposition.

It is believed that the till plain where Hoytville soils are developed has been subjected to smoothing action by wave motion. Within the Hoytville soil areas are local places that display evidence of deposition, others where the presence of more than average pebble content at the surface indicates scouring action.

The area of deposition of lacustrine materials adds supporting evidence to this theory. Because areas of till, 1 to 10 acres in extent, project up through the mantle of lacustrine materials, it is postulated that lacustrine material was deposited in the early stages of the lake before the till plain was smoothed to a relatively level plain.

The source of materials with such a high clay content as in the area of Paulding soils is one of conjecture. Leverett and Taylor (1915) state that the glacier receded from the Fort Wayne moraine beyond the Defiance moraine, then re-advanced to the position of the Defiance moraine. At this position the first major stage of Lake Maumee came into being. The extent of beachridge development indicates that the first stage of Lake Maumee remained in this position for some time.

Since the Paulding materials overlay an unleveled till plain, they must have been deposited in the early stages of the lake system before wave action could have leveled the till plain. The first stage of Lake Maumee was the only one where Paulding-like lacustrine materials could have been deposited in such a confined area. Comparable materials are not known to occur in other parts of the lake plain in northwestern Ohio. There are similar lacustrine materials, but unrelated as to source, in the Killdeer Marsh area of Marion and Wyandot Counties.

When the glacier front was at the position of the Defiance moraine, two major river systems flowed into this lake, the Tiffin from the north and the Blanchard from the south. Both of these rivers were in position to receive large amounts of debris from the front of the melting ice.

The Tiffin River has a vast area of outwash plain extending into Michigan.

This plain from north to south has well-graded sediments that become finer as the center of the lake plain is reached. Just to the north of the Paulding materials are Toledo soil materials containing more silt and less clay.

The Blanchard River likewise left a large area of medium to moderately coarse textured materials immediately east of the Findlay Bay. However, it did not leave large areas of Toledo-like silty materials comparable to those in the Tiffin River Basin.

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